Our long range plans are to develop consultation systems in anticoagulation therapy and in the interpretation of other hematological laboratory results.

B. Justification and requirements for continued SUMEX use

As our knowledge base grows, the capabilities of UNITS/AGE will become increasingly more important to us. The UNITS package has built-in means of dealing with large amounts of knowledge in a hierarchical fashion. AGE is a knowledge-based program designed to build other knowledge-based programs. To be deprived of the ability to study how these systems handle the knowledge and the actual consultation problems would be a serious impediment to our long range plans.

An ancillary, but still important, objective of our work in AI in medicine is to learn about the strengths and weaknesses of the particular AI programming systems in use and development in order to better understand how knowledge can be stored and manipulated. This understanding, in itself important, may then be applied in the design of simpler, but perhaps more accessible programs which can be implemented on micro- or mini-computers.

The question of our continued use of both EMYCIN and AGE raises the serious problem of our exceeding our storage allocation. We are prepared either to settle on one, or to propose a more formal comparison of the two systems. The choice and the mechanism for the comparison will be made in concert with SUMEX management. We feel the comparison would help us to gain insight into these systems but would make these requests only if it were clear that such a study would be of interest to others on the SUMEX resource.

9.4.2 Communication Enhancement Project

Communication Enhancement Project

John B. Eulenberg and Carl V. Page
Michigan State University

I) Summary of Research Program.

A) Technical goals.

The major goal of this research is the design of intelligent speech prostheses for persons who experience severe communication handicaps. Essential subgoals are:

(1) Design of input devices which can be used by persons whose movement is greatly restricted.

(2) Development of software for text-to-speech production.

(3) Research in knowledge representations for syntax and semantics of spoken English in restricted real world domains.

(4) Development of micro-computer based portable speech prostheses.

B) Medical Relevance and Collaboration.

Members of our group are in touch with Dr. Kenneth Colby and his group at UCLA who have been working on similar problems for people who have aphasia.

The need for such technology in the medical area is very great. Millions of people around the world lead isolated existences unable to communicate because of stroke, traumatic brain injury, cerebral palsy or other causes. The availability of inexpensive micro-processors and voice synthesizers allows development of complex experimental systems to study human communication. The knowledge gained from these experimental systems should lead in a few years to prototypes of very low cost which will permit many people to engage in the vital acts of communication required for a "normal" life in human society.

Despite the importance of the problems in this area, it has been difficult to coordinate the many professions which are involved. We believe that both research and the support of research in this area suffers from the lack of an identifiable community of workers. To alleviate this problem, we have joined with the Trace Center of the U. of Wisconsin to publish the first newsletter for dissemination in this area Called "Communication Outlook", the first issue was published in April, 1978. There are now over 1100 paid subscribers. Subscribers and contributors to the Newsletter come from a vide variety of disciplines and from many countries. John B. Eulenberg helped to organize the first Federal workshop for governmental agencies who have some interest in funding work in these areas. Represented were the Bureau of Education for the Handicapped, The Veterans Administration, The Civil Service Commission, NIH, NSF, and others. We have also been in touch with United Cerebral Palsy associations at the state and national levels. Much of our effort has been in educating those medical, educational, and governmental communities with an interest in this area on the available technology since most of them are not accustomed to funding the development of high-technology systems.

C) Progress summary.
Although some facets of the research have been underway at MSU for several years, we have been using SUMEX-AIM for three years, having received our password in March, 1977.

During the last past three years, we have:

1) Organized a research team of 4 students possessing background in artificial intelligence lead by Dr. Carl V. Page to start a semantics-speech generator. This group had a very primitive prototype (written in Sail) running in June, 1977. The system uses statistical, grammatical and semantic information to generate sentences by anticipation. A similar group was organized in 1978 but it produced well documented but not fully debugged programs.

2) Converted a large program (Orthophone) for English text to speech synthesizer codes to SAIL from Algol.

3) Obtained local support for terminals and space to use the SUMEX-AIM facility. At present, the lack of a dedicated tie-line from East Lansing to Tymshare in Ann Arbor or Detroit is a problem for us during 0600 to 0900 PST.

4) In 1978, Dr. Reid of our project designed and built a wheel-chair portable personal communication system for a 10 year old boy who has cerebral palsy. It is micro-computer based and can accept inputs via an adaptive switch from a series of menus displayed on a TV screen, via Morse code, or by a keyboard. Its outputs can be TV display, hard copy, spoken English, Morse code, or musical sounds. As the memory available for small systems will soon be substantial, we will need to specify the content and connection of the choice menus using the knowledge gained in our SUMEX-AIM project. Although our prototype for semantic generation has not run satisfactorily, it has influenced the design of the next system, the "SAL" board for wheel-chairs described below.

5) During 1979, a communication aid using knowledge sources has been built into a lap board. Called the "SAL" prosthesis (Semantically accessible language), it uses a magnetic input to translate Bliss symbols into spoken language. Some ideas from the grammatical portions of our SUMEX-AIM project have found their way into the SAL system. The SAL system consists of an aluminum encased lap tray with an array of 252 reed switches arranged in a 12 row by 21 column matrix. Spacing between switches is one inch. They are activated by a small magnet held by the user on a mitt or a finger splint. The keyboard is interfaced to a Southwest Technical

Products 6800 computer possessing 8K of EPROM and 8K of RAM. Voice output is from a Votrax VS-6 sound synthesizer while visual output is provided by a LED array. The current system allows 512 lexical items. Frame cells provide a choice of syntactic frame, which the user may specify at the inception of the formation of a sentence to supply structural information. Each syntactic frame is a skeletal syntactic phrase marker representing a class of sentence structures. After choosing a given syntactic frame, the user goes on to choose the lexical items. The generation of appropriate pronouns depends on their role in the sentence. Thus the Bliss symbol for the speaker will come out "I" or "me" depending on the role. The system uses syntactic, phonetic, and orthographic features of previous inputs in order to generate its outputs. We expect to gain experience from our SUMEX-AIM prototype to guide the choice of semantics for the successors of this system. Ten SAL boards are being built for students now.

6) Dr. John Eulenberg began his Sabbatical leave in Palo Alto beginning in September, 1979. He has been associated with the Children's Hospital at Stanford and Telesensory Systems Inc. We have found in the past that SUMEX-AIM has provided us with a means to communicate with other members of our project when they were California. It is very important for the many ongoing projects which we have to be able keep Dr. Eulenberg in close communication with the rest of our project during his leave.

7) We have built and tested a myoelectric interface and used it (together with a miniature FM transmitter) for input of changing muscle potentials into a computer. There is reason to believe that this means of input may provide a higher bit rate than other known means for those people who possess severe cerebral palsy.

8) We continue to develop basic educational software for severely impaired persons. For example we have developed a "talking" system for drilling students in Bliss symbolics. Another system we have developed teaches spelling using a voice synthesizer and TV screen. A classroom in a Northville, Michigan public school now contains a Nova 2/10 for the evaluation of our systems.

D) Up-to-date list of publications. (1976 to date)
By John B. Eulenberg

"Technical Systems Development, Headin", Interim Report, April, 1976, Experimental Applications of Two-Way Cable Delivery, NSF Grant No. APR 75-14286.

"Interactive New Hired Information Access System with Both Voice and Hard Copy Output: User's Guide to NHQUERRY", April 11, 1976 (With Steven Kludt and Jerome Jackson (Artificial Language Laboratory Report AEB 041176))

"Language Individualization in a Computer-Based Speech Prosthesis System", National Computer Conference, New York, June 9, 1976.

"Individualization in a Speech Prosthesis System", Proceedings of 1976 Conference on Systems and Devices for the Disabled, June 10, 1976.

"The LEAF Language", Interim Report, September, 1976, NSF Grant No. APR 75-14286.

"Microprocessor-Based Artificial Language for Communication Prostheses", with M. R. Rahimi, Proc. of the National Electronics Conference, Vol. XXXI, October, 1977.

"A programmable Multi-Channel Modem Output Switch", September 22, 1976, with Joseph C. Gehman and Juha Koljonen (Artificial Language Laboratory Report AEB 092276)

"SMPTE Time Code Interface and Computer-Controlled Video Switcher", with Michael Gorbutt and Dennis Phillips, Interim Report, March, 1977 NSF Grant APR 75-14286.

"Representation of Language Space in Speech Prostheses", with R. Reid and M. Rahimi, Proc. of Fourth Annual Conference on Systems and Devices for the Disabled, June, 1977.

"Administration and Management of a Computer-Based Communication Enhancement Program", with M. R. Rahimi and L. Neiswander, Proc. of Amer. Acad. for Cerebral Palsy and Developmental Medicine, October, 1977. "When [-VOICE] becomes [+VOICE]- The Phonological Competence of People Who Cannot Speak", with Carol Myers Scotton, Proceedings of the Annual Confer. of the Linguistic Soc. of America, December, 1977.

"Toward a Semantically Accessible Communication Aid", (With M. A Rahimi) Proceedings of the National Electronics Conference, Vol. xxxii, Chicago, Illinois, October, 1978.

By Carl V. Page:

"Heuristics for Signature Table Analysis as a Pattern Recognition Technique", IEEE Transactions on Systems, Man and Cybernetics,Vol. SMC-7, No. 2, February 1977.

"Discriminant Grammars, an Alternative to Parsing". with Alan Filipski, Proceedings of the IEEE Workshop on Picture Processing, Computer Graphics, and Pattern Recognition, April 22, 1977.

"Pattern Recognition and Data structures". Chapter in "Data Structures in Computer Graphics and Pattern Recognition" Edited by Allen Klinger, Academic Press, 1977.

"A Survey of Artificial Intelligence in Computer-Aided Instruction", with Alice Gable (To appear in the International Journal of Man-Machine Systems, 1979)

"Economic Consequences of Robots Possessing Computer Vision Systems", Proceedings of the Upper-Midwest Small College Computer Conference, St. Cloud State University, St. Cloud, Minn. April, 1979.

E) Funding Status.

1) Current funding.

SOURCE	AMOUNT	PERIOD
Division of Engineering Research, Michigan State University	$45,000	Sept. 1, 79- Aug. 31, 80
Northville Public Schools	$90,000	Sept. 1, 79- Aug. 31, 80
Jackson County Schools	$10,000	Sept. 1, 79- Aug. 31, 80
Jackson Foundation	$10,000	Sept. 1, 79- Aug. 31, 80
United Cerebral Palsy Foundation	$42,000	Sept. 1, 79- Aug. 31, 80
National Science Foundation (Eng-7907753)	$98,000	Sept. 1, 79- Aug. 31, 80
State of Michigan Vocational Rehabilitation	$15,000	Sept. 1, 79- Aug. 31, 80

Commitments in the grants have prevented us from using very much of these funds to support long range goals such as those communicated to SUMEX-AIM. However, the special communication devices, student and other research facilities provide the critical mass which will allow us to do the work that we have proposed. The main value of SUMEX-AIM to us is to allow experimentation with AI technology in order to develop the experience to design intelligent speech prostheses.

2) Pending applications and renewals.

Oakland County Intermediate School District - $100,000.
Genessee County Intermediate School District - $100,000.

Tuscola County Intermediate School District - $20,000.
Livingston County Intermediate School District- $50,000.

II. <u>INTERACTION WITH SUMEX-AIM RESOURCE</u>

A. Collaborations and medical use of programs via SUMEX.

We have shown Mycin and Puff to physicians and clinical staff and discussions continue with them concerning possible research. During a visit to our campus in October 1978, Dr. Bruce Buchanan lectured on Mycin and stimulated some of our Medical School faculty to explore research opportunities with us. As a consequence, Dr. Carl V. Page has participated in a proposal to NSF with Dr. Su-Wah Chan (principal investigator) titled "A Structural Analysis of Problem Complexity in Information Processing Behaviors as Related to Human Problem Solving". We hope that some other research possibilities derive from this effort.

B. Sharing and interactions with other SUMEX-AIM projects. During the past year we have had personal contact with the SUMEX-AIM staff. Dr. Eulenberg attended the 1978 Workshop in the Summer. Dr. Page used the facility while working in California as a means keep in touch with the project in East Lansing. The communication aspect of the project has been useful for us in the past and will continue to be so in the future inasmuch as Dr. Eulenberg is spending his Sabbatical in Palo Alto.

C. Critique of resource management.

We have found the staff to be professional and helpful. We have not used the system enough to comment on the management of the facility except to say that we have become somewhat disillusioned with the SAIL compiler.

III. RESEARCH PLANS (8/79-7/81)

A. Long Range project goals and plans.

We will continue to explore the interactions of different knowledge sources in the problem of generation of language. Such information as is learned will be scaled down so that it can be used in the design of portable, intelligent, speech prostheses.

B. Justification and requirements for continued SUMEX use.

We do not require any more resources than we have had in the past. Unfortunately our SUMEX research has not had the priority with us that it deserves. In one sense, our SUMEX research represents to us the future of work in this area, but we are involved with commitments for systems for communication enhancement that must be delivered soon. We expect to change the pattern of our funding to emphasize the kinds of problems we have addressed to SUMEX, beginning the process next year. Our prototype system on SUMEX has been built by volunteer student effort rather than our financial support. We hope to change this policy when pressing needs are satisfied. Our prototype has already has had some influence on the design of a wheel-chair portable system, the SAL prosthesis mentioned above. We have planned to incorporate at least one Ph. D. thesis into this research area. One of our former employees, Mr. Douglas Appelt has been doing his thesis in this area at Stanford and we believe that it is a good area. However, before we can advise a a student to start a thesis dependent on the system, we need assurance that we will have access to SUMEX for at least two years at some reasonable level comparable to what we have now.

C. Other Computational needs.

We use minicomputers and the central computers at MSU in addition to SUMEX. We have no plans to secure any additional equipment.

D. Recommendations for future community and resource development.

1. We have not heard much lately about the KRL language. If it is available or can be made available, we would be interested in considering it for our project.

2. We would be interested programs to help scale down a system developed on SUMEX-AIM to smaller machines.

3. We are interested in programs to facilitate the hardware design process for microcomputer based systems.

9.4.3 A Computerized Psychopharmacology Advisor

A Computerized Psychopharmacology Advisor

Jon F. Heiser. M.D.
Ruven E. Brooks, Ph.D.
Department of Psychiatry and Behavioral Sciences
University of Texas Medical Branch
Galveston, Texas

I. Summary Research Program

A. Technical Goals.

We are developing a computer-based automated system for education and consultation in clinical psychopharmacology. Our technical goals are envisioned in three phases:

- To develop a theory of expert teaching, consulting and decision-making in clinical psychopharmacology.
- To model this theory on a computer system which responds in real time and communicates in natural language.
- To evaluate this theory and model as a representation of psychiatric knowledge by analyzing both the performance of the system and the effort required for the system's development.

B. Medical Relevance and Collaboration.

1. Medical Relevance.

For many years, it has been recognized that potent psychopharmacological agents are frequently used in an unsystematic manner. There are at least 50 discrete syndromes currently identified in clinical psychiatry which have unique hierarchies of plausible pharmacological treatments. Each therapeutic regimen in each hierarchy may involve several classes of drugs which can often be preferentially ranked. A particular member of a class of drugs may be recommended on the basis of a patient's medical history, family history, response to previous treatments, current physical status, or current mental status. In addition, each treatment program has its own set of potential side effects, adverse reactions and drug-drug, drug-host, drug-age, drug-gender, drug-state of health, and drug-other treatment interactions.

Conventional sources of information for education or verification (books, journals, lectures, and seminars) are seldom quickly accessible or specifically pertinent. A traditional alternative is to consult a specialist. In addition to availability, reliability and validity, a good consultant has the ability to understand questions in their proper context and sequence, to give advice which can be explained or documented as needed, and to provide follow-up consultations which incorporate new information from clinical developments or additional expertise.

Our research on the Clinical Psychopharmacology Advisor is directed towards implementing all of the characteristics of a good consultant, which have only been outlined above, in a functional computer program. To our knowledge, no other computer program currently available, or under development, is pursuing all of these goals in clinical psychopharmacology.

2. Collaboration.

2.1 Principal Investigator: Jon F. Heiser, M.D., Associate Professor, Department of Psychiatry and Behavioral Sciences

2.2 Co-principal Investigator: Ruven E. Brooks, Ph.D., Assistant Professor, Department of Psychiatry and Behavioral Sciences

2.3 Pharmacist, University of Texas Medical Branch:
Carla Maria Brandt, B.S. (January 1979-present)

2.5 National Advisory Panel:

John M. Davis, M.D.
Illinois State Psychiatric Institute
1601 West Taylor Street
Chicago, Illinois 60612

Max Fink, M.D.
Department of Psychiatry
State University of New York at Stony Brook
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New York, New York 10032

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New York Psychiatric Institute
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Rockland Research Institute
Rockland State Hospital
Orangeburg, New York 10962

C. Progress Summary.

Our initial goal has been to develop a small, but fully functioning, Clinical Psychopharmacology Advisor. Approximately 250 rules, utilizing about 120 clinical parameters, were developed and used to diagnose and recommend therapy. The system, affectionately called HEADMED, had sound knowledge about the differential diagnosis of the major affective disorders and schizophrenia. The Psychopharmacology Advisor had perfunctory information concerning paranoid disorders and personality disorders. HEADMED also had skeletal knowledge about neuroses, behavior disorders, substance abuse, organic brain disorders, including both the type of brain disorder (e.g. delirium or dementia), and the cause of brain disorders (e.g. intoxication or trauma). The program has never known anything about child psychiatry, sexual disorders and other psychiatric conditions.

The HEADMED software had the capability of recommending a drug treatment, if indicated, and of cautioning about potentially harmful interactions with a compromised host and with other chemical substances. The system also could print out advice concerning dose and duration of therapy, pharmacokinetics, warnings about common side effects and possible adverse reactions.

Having been satisfied with the feasibility of using EMYCIN as a language for performing consultations in clinical psychopharmacology, our interest shifted to critically evaluating this application of EMYCIN and to modifying data structures and control mechanisms so that a a consultation process which is more natural, complete, and accurate occurs. We had planned concentrating our attention on psychiatric disorders whose management might include prescription of a tricyclic antidepressant, one of the major classes of psychotherapeutic medications, and on outputting individual case-oriented advice and precautions concerning management and monitoring of a patient receiving a tricyclic antidepressant medication (see reference I.D.5 below). Thus we have begun to develop knowledge structures which can utilize this information to compute diagnostic formulations and therapeutic plans which are highly specific to the unique properties and circumstances of a particular patient.

We have discovered what we believe is an essential design problem for medical expert systems, that of controlling the amount and the type of information which the system requests from the user. This problem is inherent in medical expert systems because of the nature of the distribution of clinical states, and the nature of the training and the background of physicians. The problem also exists for human consultants, and a complete and general solution for computer systems is probably not achievable. However, several techniques show promise for reducing the magnitude of the problem in various clinical domains. These include system use of dynamic and static domain models, user control over sophistication level, and user access to the rationales behind information requests.

A prolonged illness of the Principal Investigator prevented significant progress during the past year.

D. List of Relevant Publications.

1. Heiser, J.F., Brooks, R.E., and Ballard, J.P. Artificial Intelligence in Psychopharmacology. Abstracts - VI World Congress of Psychiatry, Honolulu, Hawaii, 28 August - 03 September 1977, page 135.

2. Heiser, J.F., Brooks, R.E., and Ballard, J.P. A Computerized Psychopharmacology Advisor. Continuing Medical Education Syllabus and Scientific Proceedings in Summary Form, The 131st Annual Meeting of the American Psychiatric Association, Atlanta, Georgia, 8-12 May 1978, American Psychiatric Association, Washington D.C., 1978, page 216.

3. Heiser, J.F., Brooks, R.E., and Ballard, J.P. A Computerized Psychopharmacology Advisor. The 11th C.I.N.P. Congress, Collegium Internationale Neuro-Psychopharmacologicum, 9-14 July 1978, Vienna, Austria, Book of Abstracts, page 233, c/o INTERCONVENTION, Kinderspitalgasse 5, A-1095, Vienna, Austria.

4. Heiser, J.F. and Brooks, R.E. Design Considerations for a Clinical Psychopharmacology Advisor. In Orthner, F.H. (ed.), Proceedings, The Second Annual Symposium on Computer Applications in Medical Care, 5-9 November 1978, Washington, D.C., Institute of Electrical and Electronics Engineers, Inc., New York, 1978, pages 278-286.

5. Cutler, N.R. and Heiser, J.F. The Tricyclic Antidepressants. Journal of the American Medical Association, vol. 240, pages 2264-2266, 1978. (Editorial comment on page 2287. Error retraction: "Corrections", vol.241, page 566.

6. Taintor, Z.C., Laska, E.M., Siegel, C., Hedlund, J., Williams, T. and Heiser, J.F. Panel: Automated Data Systems in Psychiatry. Continuing Medical Education Syllabus and Scientific Proceedings in Summary Form: The 131st Annual Meeting of the American Psychiatric Association, Washington, D.C., page 293, 1978.

7. Heiser, J.F., Brooks, R.E. A Computerized Psychopharmacology Advisor. Proceedings of the Fourth Annual AIM Workshop, Washington, D.C., page 68, 1978.

8. Heiser, J.F. and Cutler, N.R. Tricyclic Antidepressants. Letters to the Editor, Journal of the American Medical Association, vol. 242, pages 511-513,1979.

9. Heiser, J.F., Colby, K.M., Faught, W.S., and Parkison, R.C. Can Psychiatrists Distinguish a Computer Simulation of Paranoia from the Real Thing? Journal of Psychiatric Research, volume 15, pages 149-163, 1979.

10. Brooks, R.E. and Heiser, J.F. Decision-making Approaches in Medicine. Letter to the Editor, American Journal of Psychiatry vol. 136, pages 857-858, 1979, regarding the article Roberts, B.: A Look at Psychiatric Decision Making, American Journal of Psychiatry, volume 135, pages 1384-1387, 1978.

11. Mittel, N.S., Cole, J., Heiser, J.F., LaBrie, R., Taintor, Z. Panel: Computerized Psychotropic Drug Monitoring. Continuing Medical Education Syllabus and Scientific Proceedings in Summary Form, The 132nd Annual Meeting of the American Psychiatric Association, Washington, D.C., pages 317-318, 1979.

12. Brooks, R.E. and Heiser, J.F. Controlling Question Asking in a Medical Expert System. Proceedings of of the 6th International Joint Conference on Artificial Intelligence, Tokyo, Japan 1: pages 102-104, 1979.

13. Brooks, R.E. and Heiser, J.F. Some Experiences with Transferring the MYCIN System to a New Domain. IEEE Trans on Pattern analysis, Machine Intel (Special Issue Bio. Pattern Analysis), in press, 1980.

14. Brooks,R.E. and Heiser, J.F. Transferability of a Rule-based Control Structure to a New Knowledge Domain. In Dunn, R.A. Proceedings: The Third Annual Symposium on Computer Applications in Medical Care, IEEE Computer Society, pages 56-63, 1979.

E. Funding Support Status.

1. The Principal Investigator, Co-Principal Investigator, and Pharmacist are full-time employees of the University of Texas Medical Branch at Galveston, and have participated in this research as part of their assigned duties or in their spare time. Specifically, the Principal Investigator and Co-principal Investigator are assigned to work half time on this project.

2. Additional support in the form of Office and Laboratory Space, Clerical Assistance, Peripheral Data Processing Equipment, Supplies and Expenses for Traveling to Professional Meetings has also been provided by the University of Texas Medical Branch.

3. From October 1977 through June 1978, Mr. Holthus was employed half-time by the University of California, Irvine as a Research Technician in the Department of Psychiatry and Human Behavior. Mr. Holthus was assigned to work on this project and was paid $3.67 per hour.

4. A modest amount of additional support was obtained from: Title: A Computerized Psychopharmacology Advisor Principal Investigator: Jon F. Heiser, M.D. Funding Agency: Anne R. Issler Endowment Fund Department of Psychiatry and Human Behavior University of California, Irvine Total Award: $552.50 Date: January-June 1978

5. A grant application submitted to the National Institute of Mental Health in November 1977 was rejected. An application for a Career Development Award for the Principal Investigator submitted to the Veterans Administration in January 1978, was funded but rejected by the Principal Investigator in favor of accepting his current position with the University of Texas Medical Branch. Copies of these grant proposals are available upon request.

6. Two grants were submitted to the National Institute of Mental Health in November 1978. The titles are "A Computerized Psychopharmacology Advisor" and "Rule-based Tricyclic Antidepressant Knowledge System". A grant entitled "Transferability of a Rule-based Control Structure to a New Knowledge Domain" was submitted to the National Science Foundation in May 1979. All three of these grants were rejected. Copies are available upon request.

7. The Director of Professional Services, E.R. Squibb and Sons Pharmaceutical Company, has offered to support Professional Collaboration through Squibb's panel of distinguished consultants.

II. Interactions with the SUMEX-AIM Resource.

A. Collaborations and Medical Use of Programs via SUMEX.

1. The MYCIN group has collaborated with our group since work on the Psychopharmacology Advisor began. The MYCIN group supplies invaluable software support to the EMYCIN program. Our group has participated in writing documentation of the EMYCIN software which presumably is useful to all EMYCIN users.

B. Sharing and Interactions with Other SUMEX-AIM Projects.

1. Collaboration with Kenneth Mark Colby, M.D. and members of the Higher Mental Functions Project, begun two years ago, has continued in the form of performing and experiment and publishing a paper reporting a "Turing Test" which was performed on-line on SUMEX, with the psychiatrist-judges located at the University of California, Irvine, the patient-person at the University of California, Los Angeles (UCLA) and PARRY at SUMEX. Copies of this paper (see I.D.6. above: Heiser et al. Can Psychiatrists Distinguish a Computer Simulation of Paranoia from the Real Thing?) are available upon request. In addition, demonstrations of the PARRY and

DOCTOR programs have been given on-line, using SUMEX, to various groups of mental health professionals, computer scientists and other qualified and interested individuals.

C. Critique of Resource Management.

We continue to find the SUMEX resource a hospitable environment. We feel that the choice of operating system and associated utilities was an unusually good one, and it has become a standard against which we judge other systems.

III. Research Plans

A. Long Range Project Goals and Plans.

1. Evaluation of the Psychopharmacology Advisor.

When the performance of the Psychopharmacology Advisor approaches an optimal level in the judgment of the Principal Investigators and the Advisory Panels, a formal evaluation will be performed. Elaborate plans have been made for three types of evaluation: as a simulation of the Principal Investigator; as a national expert; and as an actual psychopharmacology advisor. In each evaluation the system will be tested on two sets of cases: one which represents the population of patients likely to be encountered in practice, thereby measuring whether HEADMED can do well what it must do most often; and one which represents unusual or exceedingly complicated cases, thereby measuring whether the program can do well in situations where usual practices may not suffice. Details of the evaluation plans are available upon request.

In order to evaluate the EMYCIN formalism regarding both its inherent properties as a consulting algorithm and its appropriateness for the domain of clinical psychopharmacology, we are seeking the answers to five questions:

1) Is it beneficial to capture knowledge and control structure in the same formalism?

2) Are certainty factors a useful way in which to encode uncertain information?

3) Can the needed input be captured through the parameter/value system?

4) Are the rules really modular?

5) Is the backward chaining rule structure appropriate?

B. Justification and Requirements for Continued SUMEX Use.

As mentioned in the preceding section, we consider the use of the EMYCIN software as integral to our project, at least for the next two years, or until we have learned enough about the domain of clinical psychopharmacology to know how to supersede the EMYCIN formalism.

C. Our Needs and Plans for Other Computational Resources, beyond SUMEX/AIM.

Our only immediate need for other computational resources beyond SUMEX/AIM continues to be for local, high-speed printing, preferably combined with local file storage. Our current slow-speed printing is unsuitable for listings of large rule sets or of system code. The planned acquisition of a 1200 baud printing terminal may substantially reduce the problem.

Our future plans will depend greatly on the outcome of our current effort. If the EMYCIN formalism proves suitable for our domain, we may find the conversion effort sufficiently worthwhile to transport EMYCIN to our local environment. If we discover that a major redesign is needed, we will make our future computing plans in light of that design.

D. Recommendations for Future Community and Resource Development.

We support the request for additional computing power for the SUMEX resource. We also welcome the proposal to experiment with sophisticated single-user machines.

9.4.4 Computer-Aided Refinement of Medical Knowledge

Computer-aided Refinement of Medical Knowledge

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I. Summary of Research Program

A. Project rationale

The structure and organization of any representation for medical knowledge determines the effectiveness of that representation for human or automated problem solvers. The construction of a consulting system requires the description of the relevant medical expertise at a high level of specificity and completeness. Thus, the act of constructing an automated problem solver can actually result in a "refinement" of medical knowledge as inconsistencies are weeded out and gaps are filled in. At present, such refinement is directed toward improving the performance of the automated consulting program. Although such improvement will continue to be a major goal for refinement, this project will emphasize processes which result in a presentation of the refined medical knowledge in forms suitable for assimilation by human problem solvers.

B. Medical Relevance and Collaboration

The management of cancer patients by the administration of chemical agents is a complex and increasingly successful medical procedure. The extensive use of cancer chemotherapy protocols provides both a source of medical knowledge for inclusion in an automated problem solver and a vehicle for introducing refined knowledge back into medical practice. Our initial thrust will deal the problem of protocol construction (either for a research trial or for an individual patient). Initially, our efforts will help to produce individual protocols, but our long term refinement goals are to provide additional insights into the process of protocol construction and to patient selection. These areas of expertise will become increasingly important as the routine management of chemotherapy ceases to be the exclusive domain of the clinical oncologist and moves into the realm of internal machine.

We are working closely with two practicing oncologists:

John Schmale, Hematologist-Oncologist, Christie Clinic, Champaign, Illinois; Clinical Assistant Professor, School of Clinical Medicine, University of Illinois.

Allen Hatfield, Head, Department of Oncology, Carle Clinic Association, Urbana, Illinois; Assistant Professor, School of Clinical Medicine, University of Illinois.

C. Research in Progress

We are just beginning this research effort and are still assembling staff and support. We are making some preliminary "pencil and paper" knowledge bases in order to assess the applicability of specific refinement techniques. As our efforts increase in scope, we will call upon consultants from outside the University of Illinois. We will work with Emil Freireich, David Wirthschafter, and John Laszlo both to acquire knowledge for refinement and to distribute the refined knowledge back into the medical community.

D. Relevant Publications

Although this specific research project has not yet produced any publications, the three articles listed below underlie much of the proposed research:

Baskin, A. B., "Logic Nets -- Semantic Networks and Variable-valued Logic," to be published in Int. J. of Man-machine Studies, 12, 1980.

Michalski, R. S., "Knowledge acquisition by encoding expert rules versus computer induction from examples: a case study involving soybean pathology," to be published in Int. J. of Man-machine Studies, 12, 1980.

Michie, Donald, "A theory of advice," in Machine Intelligence 8, (Elcock and Michie, eds.) pp. 131-168, Ellis Horwood, New York: John Wiley, 1977.

E. Funding support

We are in the process of attempting to secure both internal and external support for this research. A research proposal to the National Library of Medicine is pending a final review by the Board of Regents (as of 5/6/80). Internal University of Illinois support and the proposals listed below will provide major support for this research project:

> Computer-aided Refinement of Medical Knowledge -- a grant application under consideration by the National Library of Medicine, Allan H. Levy, principal investigator, University of Illinois, proposed budget: 8/1/80 - 7/31/85, $1,232,053 in direct costs.

We expect the participation of several of our physician in computer science trainees in this research project. These are physicians who are enrolled in the Master of Science in Computer Science program at the University of Illinois. Physician trainee support is provided by:

> Physician Computer Science Training -- (1 T15 LM 07011) National Library of Medicine, National Institutes of Health, 7/1/76-6/30/81, $804,262 in direct costs, Allan H. Levy, Principal Investigator.

II. Interactions with SUMEX-AIM Resource

Because we are still assembling staff for this research project, our interactions with the SUMEX facility and its staff have been minimal. We have begun to use the system on a pilot basis and we expect to be using the system extensively by the end of August, 1980. We anticipate extensive consultation with the staff at SUMEX as we begin to use the Resource. We have begun to establish collaboration with Dr. Shortliffe. Our refinement techniques are intended to complement the problem solving techniques being developed by the ONCOCIN project. We view the possibility of collaboration with members of the SUMEX-AIM community as an important part of the Resource and a principal reason for our joining it.

We expressly intend to develop tools for knowledge refinement and to make them available to the SUMEX-AIM community. The existence of a number of knowledge-based systems on SUMEX reduces the logistical problems which would otherwise result from an attempt to share the tools we develop.

III. Research Plans

A. Project goals and plans

The application of the computer as an aid in medical problem solving is fundamentally dependent on the formalization of the knowledge of medical experts. Currently, this formalization is a tedious process requiring a collaboration between a medical expert and a knowledge engineer with little help from the computer. This research project addresses the problem of using computers to improve and simplify the formulation and organization of medical knowledge. Specifically, the goals of this research are:

1) to investigate the theoretical problems of knowledge refinement and to develop an experimental system of programs for computer-aided knowledge refinement. In particular, the system will provide tools for improving knowledge representations, for testing correctness, for removal of errors and omissions, for detection of inconsistencies, and for simplification and generalization of medical decision rules. Such refined knowledge will be presented in both an automated and a printed form.

2) to integrate the resulting tools into a package available to the SUMEX-AIM community.

3) to establish a knowledge base for use in the management of patients receiving cancer chemotherapy. Such a knowledge base will be valuable both as a test bed for the refinement system and for its own merit. Knowledge concerning cancer chemotherapy is rapidly increasing in complexity as new drugs and treatment schedules are evaluated.

4) to analyze the strengths and weaknesses of different knowledge refinement techniques and to test the adequacy of various knowledge representation schemes including the integration of rule-based systems and semantic network representations of structured knowledge.

The definition of precise near-term goals will have to await the final determination of levels of available internal and external support. We intend to begin the migration of knowledge representation and refinement tools which exist at the University of Illinois onto the SUMEX-AIM system during the next year. These programs will serve as a basis from which new and extended tools for knowledge refinement will evolve.

B. Access to SUMEX-AIM

The resource management and communication facilities supported by SUMEX-AIM are essential to the research in this project. Without the support for knowledge engineering already provided by SUMEX-AIM, extensive redundant local development and support efforts would be necessary. Although local computing facilities can easily handle the computational load of the proposed research, the existing tools already developed on SUMEX-AIM will allow the research to progress more rapidly.

C. Additional computing resources

As outlined in our pending research grant application, we view SUMEX-AIM as a development medium and not as a final service delivery vehicle. For this reason, we anticipate the need for a locally dedicated machine on which we can use our knowledge refinement tools in a routine production mode. We are separately seeking funds to support this local machine. We recognize that all of the techniques we propose to use will not scale down to a small computer (e.g. LSI 11/23), but many will. In addition, the effective dissemination of refined knowledge may require the use of small "personal information managers." We have begun research in this area and will continue it with our own funds. Our local effort with "personal" machines will complement that proposed as a mainstream SUMEX-AIM activity.

D. Future requirements

If our knowledge base construction and refinement efforts are successful, our requirements for bulk storage attached to SUMEX will increase dramatically over the next five years. Accordingly, although our own needs alone would not justify the proposed extensions to bulk storage, we strongly endorse the hardware bulk storage purchases outlined for the Resource. The availability of bulk stores with the performance proposed will significantly facilitate our research project in the years 1983-1986.

Programs and data bases already developed at the University of Illinois could be most effectively integrated into our project on SUMEX-AIM if a high data rate connection to a commercial carrier existed. In addition, the deployment of subsets of our knowledge base on cancer chemotherapy will require an ability to transfer large files from SUMEX-AIM. Although these operations can be performed with magnetic tapes, a high speed data link is much more desirable. We will coordinate our efforts in this area with the efforts of the SUMEX-AIM staff so that we are able to benefit from high data rate access to SUMEX when it can be provided.

9.4.5 Interactive Statistical Package Advisor

An Interactive Statistical Package Advisor

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I. Abstract

The availability of multivariate statistical analysis packages such as BMDP, SPSS, and SAS has made the use of multivariate analyses an essential part of research in many areas. For researchers in these areas, the problems these packages pose are, first, to select from the analyses available those that are appropriate to the particular experimental questions being investigated and, second, to set up the control language necessary to run the analyses. The work proposed here is an aid to accomplishing these tasks in the form of an interactive statistical package advisor computer program. The user will describe to the program the data that has been collected and the experimental questions that are to be answered, and the advisor program will respond with suggestions as to the analysis and, if desired, will create the necessary control language to run the analysis.

In the initial work on this project, it will be assumed that the user has already consulted a statistician on design of the study so that the collected data is appropriate to the questions.

The proposed architecture of the system consists of a semantic parser for interpreting user input and a rule-based reasoning system for deducing the kind of analysis and the necessary control language. The rule-based reasoning system would be the EMYCIN programming system (VanMelle. 1979). The semantic parser would be similar to one already constructed for parsing natural language case summaries into parameter values in the MYCIN system (Bonnet, 1979).

This proposal is currently under consideration by both the National Science Foundation and the National Library of Medicine.

II. On Doing A.I.M. Research Outside of a Major A.I. Center

A major requirement of Artificial Intelligence in Medicine is to have sufficient access to both medical and artificial intelligence expertise and facilities so that the product of such research is relevant to both fields.

Rarely will one site combine access to both kinds of knowledge. My own situation is an illustration of this problem. I am located in the nation's fifth largest medical center, within a five minute walk of over 650 medical science specialists, so that I have excellent access to medical expertise. On the other hand, the nearest computing facility which makes some attempt to support A.I. systems and languages and which sells time to outsiders is located in Austin, Texas, a mere (Texas-style) 300 miles away. (Because of anomalies in intrastate versus interstate phone rates, it is actually cheaper in the evenings to call San Francisco than Austin.) While there are machines, such as the Cyber 173 in Houston, which could potentially support A.I. research, the responsibility for installing and maintaining A.I. languages would be largely mine. Similarly, the costs of programming support make purchase of my own hardware prohibitively expensive. If A.I.M. research is to be conducted in medical centers other than those fortuitously located near a major computer science department, then continued support of national centers such as SUMEX will be needed.

9.4.6 Conceptual Structures for Medical Diagnosis [Rutgers-AIM]

Conceptual Structures for Medical Knowledge Representation

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I. SUMMARY OF THE RESEARCH PROGRAM

I.A. Project Rationale

ABSTRACT

This project investigates a new approach to medical knowledge representation in the computer so that efficient and effective diagnosis, consultation, and information storage and retrieval systems can be designed. The approach is based on the notion that knowledge representation should be organized around the deep conceptual structure of a field of medicine. We study the principles governing the organization of the conceptual structure, which can be viewed as a way of organizing the conceptual specialists working together as a community of experts. We are building new diagnosis, consultation, patient data assistant and Radiology Specialist systems based on this approach. We also plan (at a future date) to examine the feasibility of using diagnosis systems as an experimental tool to evaluate the value of different symptoms, test data and theories in concluding a successful diagnosis. This is deemed to be a novel and potentially far-reaching application of biomedical computer systems.

RATIONALE DESCRIPTION

The objective of this research is to develop principles of knowledge representation in the computer to enable efficient and natural interaction with the system to store and retrieve medical knowledge. There should be no conceptual barrier between the human and the machine. Our main thesis is that this knowledge organization must have a deep structure that corresponds to the conceptual structure of the particular field of knowledge, and that there are definite principles that determine the form and content of these conceptual structures. We believe that whatever the purpose of knowledge representation--diagnosis, data base organization, information storage and retrieval, reading and storing of imaging data, etc.--the conceptual structure organizes the knowledge in such a way that effective, efficient access to knowledge fragments can be achieved, The efficiency of this structure is a major reason for the power of problem-solving that experts demonstrate.

The heart of the project is the development of a medical diagnosis system for Cholestasis. Since we feel that a good test of any knowledge representation scheme is in diagnosis and consultation, the near term goal is to demonstrate the power of the ideas by designing diagnosis and consultation systems for nontrivial subdomains of medicine. As part of this research we shall also develop principles of patient data organization, and a structure to represent imagery data at various levels of descriptive abstractions. The long term goal of the program is to develop and apply the conceptual structures for a variety of important information processing tasks in medicine: fact-finding, diagnosis, consultation, data base organization, interpretive reporting, etc.

There is another interesting, and potentially far reaching, application that should be mentioned here. In diagnostic medicine, there is often a question about the value of certain symptoms of lab data in concluding a successful diagnosis. One way to test this would be to assign the same case with and without the particular set of data to the same (or similarly trained) clinician and examine the result of the diagnosis. This should be repeated with a large number of different cases for statistically reliable conclusions. Obviously this is hard to do in view of the fact that physician time is a very valuable commodity, and further it is hard to eliminate effects of memory of the same case with a different set of data. We believe that computer-based diagnosis systems are promising technological tools in this problem area. The effects of different data can be ascertained by subjecting the computer-based diagnosis system to various inputs. This notion can be carried even further. Suppose there are contending theories or conceptualizations of a field of medicine (as in cholestasis). The problem-solving efficiency of the contending theories can be evaluated by embodying each of them in the conceptual structure representation, designing the diagnosis system around it and testing each with data in real cases.

If properly developed this could be an important application area for biomedical information systems. Knowledge representation research clearly plays a crucial role in the development of such systems.

I.B. Medical Relevance and Collaboration

The medical relevance is indicated by the following aspects of the project:

(1) The development of MDX, a medical diagnosis system in the domain of cholestasis.

(2) The development of PATREC, a patient data base system.

(3) The development of RADEX, a computer-based radiology consultant.

(4) Plans for the development of a system to evaluate the effectiveness of various types of information in arriving at a diagnosis.

Our medical collaboration takes place through the following channels.

(1) Jack Smith, M.D., is a resident in pathology at Ohio State University Hospitals. He is also working on his Ph.D. in Artificial Intelligence in Medicine, and the research on this project will constitute his dissertation. He is our most active medical collaborator.

(2) Douglas Levin, M.D., a prominent Columbus hepatologist, and a clinical faculty member at Ohio State University College of Medicine, is our source of medical expertise in cholestasis.

(3) Carl Speicher, M.D., Director of Clinical Laboratories at OSU Hospitals, is our collaborator in the Patient Database and the associated interpretive reporting work.

(4) Joseph Schultz, M.D., a radiologist at Riverside Hospital has been our collaborator in the imaging interpretation and representation aspects of our project.

I.C. Highlights of research progress

ACCOMPLISHMENTS

The design and implementation of a working medical diagnosis program, called MDX, which was started in the last quarter of 1978, was completed in this past year. MDX, which is still limited to a small domain of medicine, has been successfully tested on a set of cases from medical journals, local university hospital and private practice.

The MDX system contains two major sub-systems, in addition to the diagnosis component, which are important in their own right. A patient data management system, based on a conceptual representation of medical data entities, has been implemented as part of the MDX system. It has two purposes. First, it manages all patient data for the diagnostic system in MDX and answers questions about the patient data. Second, this patient data management system is being used as a vehicle for research into design of AI-based data models and development of flexible and easy-to-use information management systems.

The second major sub-system in MDX is a radiology consultant, called RADEX. It provides consultation on the radiological data obtained from different xrays and cholangiograms. It also maintains an anatomical and physiological model of the patient.

RESEARCH IN PROGRESS

(i) Extending the domain of MDX to include all intra-hepatic diseases (including drug-related disorders). The goal for the next two years is to build conceptual experts for all liver diseases.

(ii) The data base model is being expanded to represent temporal information. This would allow temporal questions to be answered and enable causal inferences to be made.

(iii) A separate sub-system for preparing interpretive reports of clinical lab data is under development. The interpretive reports would present a highlighted summary of major clinical data and provide diagnostic suggestions.